Repair of a Hull 15 m below the Waterline

Since circumstances prevented the vessel from entering dry dock, the repairs had to be completed while it was afloat

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Accidents seem to happen at the most inconvenient times, so it is important to know who to turn to when they happen. When a 50,000-ton product tanker ended up with a hull breach while taking on cargo in a loading facility in Venezuela, the owner turned to Miami Diver LLC, a founding member of the Subsea Solutions Alliance, a global network of specialized underwater ship repair contractors that also includes Parker Diving Service LLC and Trident BV.

The following is a chronological review of the events, from the accident, through damage review until the successful repair of the vessel.

The Tanker

The vessel is a 50,000 MT ice-classed product tanker (Fig. 1), built in 2009. The 183-m-long double-hull ship is classed by DNV and RINA. In the area of the damage, the hull is constructed from 13.5-mm-thick higher tensile steel AH36.

The Accident

In May 2012, the tanker was loading jet fuel in a tanker port in Venezuela. During the loading operation at the terminal, the tanker sank deeper into the water with every ton of cargo being...
pumped into the tanks. Nobody knew that a submerged obstacle, most likely in the form of a broken pile, was hidden below the waterline, invisible to the officers and crew of the vessel. While increasing her draft through the increasing weight of the cargo, the submerged piling finally pierced its way through the hull of the vessel, allowing the ingress of seawater into the portside water ballast wing tank.

**Damage Assessment**

Despite the damage, the tanker left Venezuela and sailed to Aruba in the Caribbean Sea, where an initial evaluation of the damage was performed by a local dive company. After the assessment, the owner of the tanker contacted the Miami Diver office in Curaçao.

The damage proved to be severe (Fig. 2), preventing the vessel from sailing to its destination. Class would only allow the vessel to continue the journey if the hull breach was fixed permanently. Since the vessel was fully loaded, dry-docking was out of the question. The repairs needed to be performed with the vessel afloat. It was discussed with the owner and class to sail to Curaçao and perform the repairs with the vessel at berth in the clear waters of the sheltered Caracas Bay. Miami Diver’s engineering department developed a detailed repair procedure that was submitted and agreed to by the owner and class, suggesting a no condition once the repair was completed.

**Attending the Vessel**

With the arrival of the vessel in Curaçao, a team of divers, welders, and the welding engineer were deployed from Miami, Long Beach, and Curaçao to attend the vessel. The initial inspection dive revealed an approximate 400-×-500-mm hole in the hull of the vessel and deformed hull plating in the vicinity of the hull breach. In addition to the aforementioned damages, the bilge keel and grounding bar were also found to be damaged — Fig. 3.

The bilge keel and grounding bar had to be trimmed back to allow for the installation of the cofferdam and the insert plate. The trimmed bilge keel and grounding bar were mechanically profiled to match the original form.

**Templatting, Engineering, and Building the Cofferdam**

To allow the repair work to be performed under dry conditions, a cofferdam was engineered by Miami Diver.

To ensure that the cofferdam would be large enough to enclose the area of the deformed hull, divers laid out the area the cofferdam needed to cover and communicated the measurements to the engineering department.

Since the damage was in the turn of the bilge, the transition between the flat bottom and sidewall of the ship, divers templated the contour of the area to be
enclosed by the cofferdam. The area covered by the cofferdam needed to be large enough to cover the deformation in the hull caused by the impact.

Based on information and sketches provided by the divers, the cofferdam was modeled to meet the required 4-times safe working load at 14 m depth. Complete built drawings were produced to ensure the cofferdam was built in accordance to the modeling profile.

The cofferdam was built from 8-mm ASTM A36 steel in the facilities in Curaçao — Fig. 4.

Preparing the Insert Plate

The deformed and breached shell plate section needed to be removed and replaced with a rectangular insert plate, approximately 2185 × 1422 mm in size, with the corners prepared with class-required radii.

The insert plate, fabricated from 15-mm-thick EH36 class-approved steel was cut to size, prepared for welding with an approximate 37.5-deg bevel and rolled to match the curvature of the hull. The preparation of the insert plate was performed locally in Curaçao.

The track with customized ceramic backing tiles develop by Miami Diver was fitted around the peripheral edge of the insert.

Lifting lugs were welded onto the rec-
Fig. 5 — Diver welder welding a lifting lug to the hull.
tangular insert plate to allow for easier handling. After preparation of the insert plate was completed, the plate was placed into the cofferdam.

**Installing the Cofferdam**

The cofferdam was fitted with a closed-cell foam gasket material around the outer perimeter. It was centered and installed over the breach and deformation, overlapping the weld zone 500 mm, to shield the welding area and heat-affected zone.

Weld fixtures were wet welded to the ship hull (Fig. 5) by diver welders to hold the cofferdam in place.

After installation, the cofferdam was dewatered and checked for leaks prior to cutting and welding work to be performed from the inside.

**Removing the Damaged Shell Plate Section from the Inside**

The damaged section of the hull plating was removed by oxyfuel cutting from inside the cofferdam. The edges of the cut area (future weld joint) were ground smooth and beveled (Fig. 6) to approximately 37.5 deg. The corners were prepared with a 100 mm (4 in.) radii.

**Preparing the Weld Joint**

To allow unrestricted access for removal of the damaged hull section and installation of the new insert plate, frames needed to be cropped and/or temporarily removed. The welds between the web frames and hull were carefully removed by gouging the weld. In the area

![Fig. 6 — Grinding performed to prepare the joint for welding.](image1)

![Fig. 7 — Insert plate being installed.](image2)

![Fig. 8 — Welding the root from inside the cofferdam.](image3)
of the intersection between the web of the frame and weld joint of the insert plate, weld access holes were removed from the web member, sufficient in size to allow unrestricted access to the weld joint to be welded and tested.

Installing the New Shell Plating

After preparation of the weld joint, the insert plate was pulled tight against the outside of the shell plating with a consistent root opening of about 10 mm. The plate was secured in place with weld fixtures — Fig. 7. Prior to welding the insert plate, the previously cropped and/or removed frame members were reinstalled and tack welded into place. The preheat temperature of 80°C was controlled through heat-indicating crayons.

Root Opening with Ceramic Backing

Ceramic Inclusion

While welding the root, welders experienced a “popping” of the ceramic backing resulting in undesirable rejectable inclusions in the root of the weld. It appeared that the ceramic was emerged in the seawater for too long, picking up moisture that could not be released through preheating.

It was discussed with the owner and surveyors to cut a 510- × 660-mm manhole into the center of the insert plate, backgouge the root pass from the insert plate to remove all inclusions, and reweld the root from inside the cofferdam. The manhole was welded on ceramic backing. Both classification societies DNV and RINA agreed to the proposal.

After completion of the weld between the insert plate and hull, the manhole was cut in the center of the insert plate to gain access to the root side of the original joint.

The root pass was removed by carbon arc gouging, followed by cleaning the joint by grinding and rewelding the root with the SMAW process (Fig. 8) in the overhead position.

Welding the Root from Inside the Cofferdam

After welding was completed, visual and ultrasound inspection was performed on the weld between the insert plate and hull plating. The weld did not reveal rejectable indications.

Reinstalling the Manhole Cut-Out

The weld joint of the insert plate for the manhole was prepared and welded on ceramic backing. It was subject to visual and ultrasound inspection after completion. The welds passed without rejectable indications — Fig. 9.

All temporary removed frames were reinstalled with weld sizes matching the original weld sizes.

Welding

Underwater Wet Welding

Underwater wet welding was only performed to attach installation aids for the cofferdam, which were removed after completion of the work.

All underwater wet welding was based on AWS D3.6:1998 Class A welding procedure qualifications (WPO), employing the wet shielded metal arc welding process with Hydroweld FS electrodes. All welds were executed as multilayer fillet welds in T- and lap joints.
Top Side Welding

Top side welding was performed as a permanent repair in the dry. Top side welding was performed in accordance with the class-approved welding procedure specification (WPS), employing the flux cored arc welding process (FCAW) under a shielding gas consisting of 75% argon and 25% CO2 and shielded metal arc welding (SMAW) process with class-approved E7018 low-hydrogen electrodes.

Complete joint penetration welds were either welded on non-consumable ceramic backing or backgouging the root and rewelding the root side of the joint.

Removing the Cofferdam

After removal of the cofferdam (Fig. 10), previously welded installation aids were removed and any weld metal remaining on the hull was ground flush.

Underwater magnetic particle (MT) testing was performed on the ship hull where installation aids for the cofferdam were removed.

Corrosion Protection

After welding was completed and the welds passed nondestructive examination, corrosion protection in the form of Hycote 151, an underwater, two-component, polyamine-cured epoxy coating, was applied over the welds, areas adjacent to the welds, and areas where the corrosion protection had been removed or burned off during welding. This assisted in the protection and reduction of metal wastage in those areas due to immersion in saltwater by providing a permanent anticorrosive protection. Preparation of the coating of the internal paint system was performed by the vessel’s crew.